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Laser stereotaxy for malignant gliomas: 2001–2004

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Abstract

Tumours of the central nervous system represent a therapeutic challenge. Although there is a multitude of histological subgroups, the main entities are of glioma origin. The majority of these lesions have an infiltrative nature, which is, in conjunction with the vicinity of highly specialized eloquent areas, highly demanding on the surgical skills and technologies applied. These tumours will invariably recur, most often even at the very site of the apparently "complete" resection. This has created local therapies for direct intra cavitary treatment of the surface and for interstitial treatment of the immediately adjacent tissue. Sixteen patients suffering from recurrent Glioblastoma multiforme (GBM) were treated by Nd:YAG laser irradiation in the framework of a salvage therapy. The underlying concept is the cytoreduction by partial coagulation of the tumour. MRI follow-up examinations revealed a volume reduction of the laser-irradiated areas, while the untreated parts exhibited a more or less progression. The survival time after the diagnosis of the recurrence was about four times longer than the natural history of the disease would suggest. The conclusion is that cytoreduction by laser irradiation might be a promising option for patients suffering from infiltrative gliomas. Future work should optimize the therapeutic regimes and evaluate this treatment approach in controlled clinical trials. In this article we will summarize the technical and clinical results induced by interstitial laser application in cerebral gliomas.

Keywords: Brain tumour; Glioma; Interstitial thermotherapy; Laser induced; MRI guided therapy; Recurrent glioblastoma multiforme; Survival

Introduction

Tumours of the central nervous system represent a therapeutic challenge. Although there is a multitude of histological subgroups, the main entities are of astrocytic and oligodendrocytic origin. The majority of these lesions have an infiltrative nature, which is, in conjunction with the vicinity of highly specialized eloquent areas, highly demanding of the surgical skills and technologies applied. There are various approaches to the treatment of neuroepithelial tumours. Surgery is the first treatment option for primary and recurrent lesions. However, there are cases, where either surgery predictably harbours significant morbidity or general health issues preclude long procedures. In much the same way it is certain that due to the infiltrative nature of these lesions, a surgical cure is rarely achieved. The diversity as well as the quality of the tools at our disposal has

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improved significantly over recent years. It becomes more of a challenge to comprehend and correctly employ the different therapeutic modalities. Still it is sometimes discouraging that even with such a potent armamentarium, this grave disease entity takes an unstably lethal course. Presently our best achievement is to improve or at least maintain the patient's quality of life for as long as possible and ameliorate symptoms. In these cases, radiation or interstitial therapy, by using stereotactic principles remains an alternative option. As for interstitial therapies, radioactive seed implantation as well as interstitial laser-induced thermotherapy enable minimal interventions, which allow pathologic diagnosis combined with local treatment [1].

Interstitial laser therapy using diffusor fibre tips

Laser induced interstitial thermotherapy (LITT) in glioma is performed via flexible light guides. In general, fused silica fibres of 400 or 600 μm in diameter are used. These are characterized by a damping factor of a less than 1 dB/km (1064 nm). Thus, transmission losses due to the fibre material is almost negligible with light guides of a typical length between 10 and 12 m. This length is required if LITT is monitored by magnetic resonance (MR) imaging. In this case, the laser must be positioned outside the MR-room to avoid interactions with the magnetic field. Transmission losses are predominantly due to the Fresnel reflection at the air/fibre interfaces within the fibre coupler. The major goal of interstitial thermal therapy is the heating of a given tissue volume without adverse effects such as charring or shock waves due to vaporization at the probe tip. Consequently, the peak temperature at the probe tip must not exceed 100 °C. This limits the peak power energy per given time and probe surface area. On the other hand a minimal radiant power density is required to achieve a sufficient temperature rise for tissue denaturation. The high power density at the conventional fibre tip often resulted in an overheating of the tissue surface with consecutive vaporization and carbonization. In this situation, no longer does tissue irradiation takes place and the heating process is mediated by thermal conduction only. The technique was overcome using optical diffusors; such diffusors emit laser light over the entire length of the fibre tip, significantly reducing the power density and the penetration depth is dependent on the optical tissue properties (absorption, scattering, blood content) at the wavelength used. These devices allow to couple between 5 and 8 W into the brain tissue without adverse effects. The resulting laser lesion is also dependent on the length of the optical diffusor (see Fig. 1).

At a temperature above 60 °C, a direct thermal coagulation is induced resulting in an necrosis of 2–3 cm in radial diameter. In the areas beyond the induced necrosis, temperatures are lower, however, still above 38 °C. Thus, the total thermally treated area typically extends over 3 and 4 cm in radial diameter. The final lesion sizes, however, are also dependent on the exact optical properties of the irradiated tissue as well as its blood perfusion. For on-line control, temperature monitoring was performed using the experimental software package based on the temperature-dependent phase shift of the MR signal as mentioned above. The actual temperature distribution could be displayed as colour-coded images as well as time course of the hot spot temperature (see Fig. 2). Laser irradiation was ceased when temperature monitoring revealed a steady-state temperature profile within the heated tissue [2].

Image-guided laser fibre adaption

LITT procedures in the open MR Signa SP/ 2 are dependent on MR-compatible and artifact-free instruments. A guiding device (NeuroGate, Daum, Schwerin, Germany) has been used in combination with the

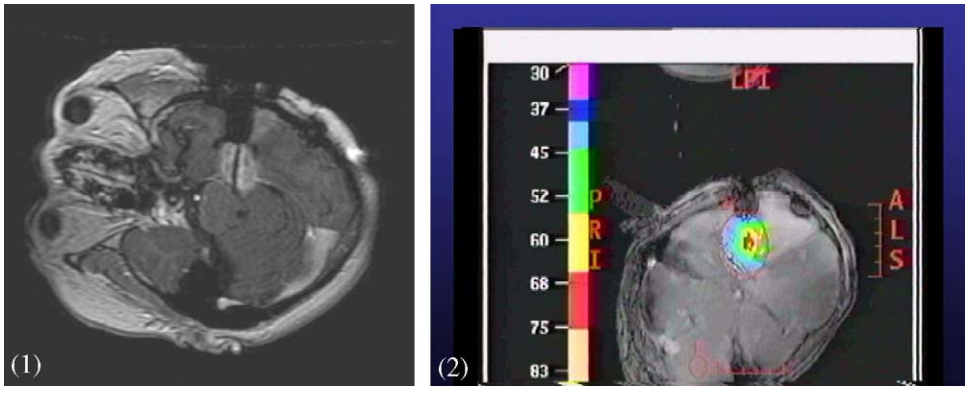

Fig. 1-2. (1) Laser light guide in place after repositioning and insertion of the applicator (note the artifact of the light guide's marker (magnetite) touching the brain tumor and the artifact of the diffusing tip within the tumor). (2) The actual temperature distribution is displayed as colour-coded, near real-time MR images.